Technology Review:

Liquid Filled Heat Sinks, 2002-2013

Qpedia continues its review of technologies developed for electronics cooling applications. We are presenting selected patents that were awarded to developers around the world to address cooling challenges. After reading the series, you will be more aware of both the historic developments and the latest breakthroughs in both product design and applications. We are specifically focusing on patented technologies to show the breadth of development in thermal management product sectors. Please note that there are many patents within these areas. Limited by article space, we are presenting a small number to offer a representation of the entire field. You are encouraged to do your own patent investigation. Further, if you have been awarded a patent and would like to have it included in these reviews, please send us your patent number or patent application.

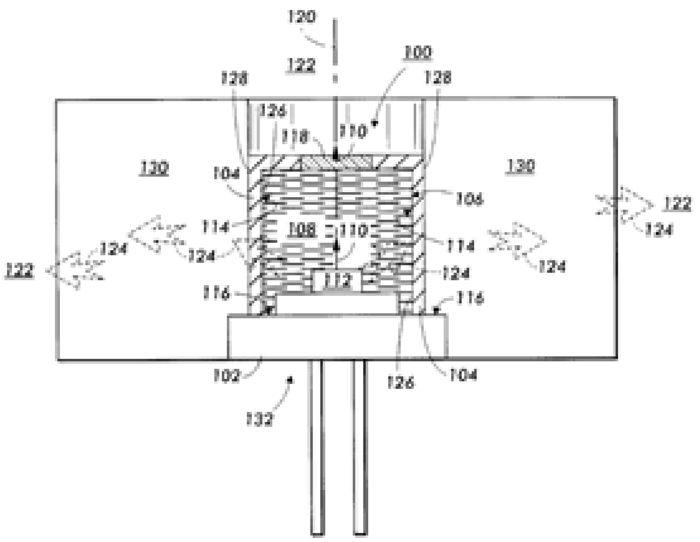
In this issue our spotlight is on liquid filled heat sinks. There is much discussion about its deployment in the electronics industry, and these patents show some of the salient features that are the focus of different inventors.

OPTICALLY TRANSPARENT, HEAT CONDUCTIVE FLUID HEAT SINK

US 6,480,515 B1, Wilson, J.

The fluid heat sink 100 has a hollow, heat conductive housing 104 defining an interior cavity 106. The interior cavity is filled with an optically transparent, heat conductive fluid 108.The housing 104 in this illustrative embodiment is cylindrical. The heat conductive housing is preferably metal, preferably aluminum or copper.The laser diode 102 is a conventional laser diode for emission of a light beam 110 of a single wavelength through the laser diode aperture 112 as is known in the art.
The open circular edge 114 of the cylindrical heat sink housing 104 is attached to the emission surface 116 of the laser diode 102. The circular edge 114 and the heat sink housing 104 surround the laser diode aperture 112 with the aperture ideally being positioned in the center of the circular edge 114 and the heat sink interior cavity 106.
The heat sink 100 includes an optically transparent window 118 on the closed end 120 of the housing 104 which is opposite the open circular edge 114.

PATENT NUMBER	TITLE	INVENTORS	DATE OF AWARD
US 6,480,515 B1	OPTICALLY TRANSPARENT, HEAT CONDUCTIVE FLUID HEAT SINK	Wilson, J.	Nov 12, 2002
US 8,262,263 B2	HIGH RELIABILITY COOLING SYSTEM FOR LED LAMPS DUAL MODE HEAT TRANSFER LOOPS	Dinh, K.	Sept 11, 2012
US 2013/0063896 A1	HEAT SINK APPARATUS AND ELECTRONIC DEVICE HAVING SAME	Satou, k., et al.	Mar 14, 2013



The output window 118 is positioned substantially parallel to the emission surface 116 of the laser diode 102. The output window 118 is positioned opposite the laser diode aperture 112 in the heat sink 100, directly in the optical path 120 of the emitted light beam 110.

The interior cavity 106 of the heat sink 100 is filled with an optically transparent, heat conductive fluid 108. The light beam 110 will be emitted by the laser diode 102 through the aperture 112 and propagate along the optical path 120 through the optically transparent, heat sink fluid 108. The light beam 110 will then be transmitted through the heat sink output window 118 to the ambient atmosphere 122.

The fluid 108 in the fluid heat sink 100 can either be a liquid or a gas. The technical requirements are that the fluid 108 be optically transparent to the wavelength of the light beam 110 emitted by the laser diode 102 and that the fluid be heat conductive to dissipate the heat generated by the laser diode 120 during light emission away from the laser diode. Examples of such a fluid, which vary in optically transparent wavelength range and heat dissipation rate, are helium, water, deionized water, a solution of water and glycerine, perflurocarbon fluid, fluorinert, ethylene glycol, and aqueous solutions of baruium chloride, stronium chloride or barium iodide.

The optical path 120 of the light beam 110 from the aperture 112 to the output window 118 through the heat sink fluid 108 is through the center of the cylindrical heat sink housing 104.

Heat 124 generated by the laser diode 102 is emitted through the surface 116 of the laser diode 102. The fluid 108 transfers the heat to the interior wall 126 of the cylindrical heat sink housing 104. The heat 124 flows through the heat sink housing to the exterior wall 128 of the housing. The heat 124 can radiate out into the ambient atmosphere 122 is transferred to a secondary heat sink 130 as is known in the art. The secondary heat sink can be a passive or active heat sink with or without heat radiating fins or can be a thermoelectric cooler. The secondary heat sink 130 will transfer the heat 124 to the ambient atmosphere 122.

The center positioning of the aperture within the symmetrical fluid-filled cavity and housing provides uniform radiation and uniform convection of the heat from the laser diode to the fluid heat sink. The output window 118 of the fluid heat sink 100 must also be optically transparent to the wavelength of the light beam 110 emitted by the laser diode 102. It is not required, but it is physically and optically possible, that the output window 118 also be heat conductive to dissipate the heat generated by the laser diode during light emission away from the laser diode. Examples of materials for the output window would be quartz or BK7 glass.

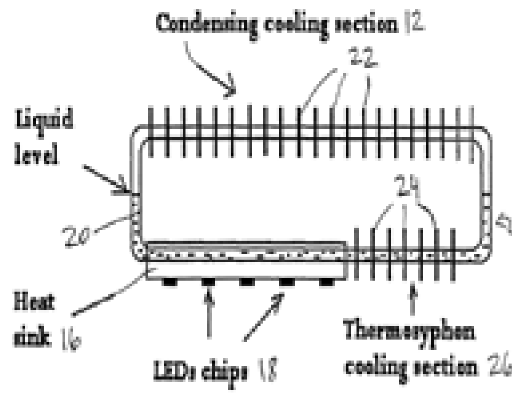
The output window 118 can also be angled at Brewster's angle to reduce loss, to prevent feedback and to polarize the emitted light beam. Depending upon the size of the fluid molecules and their density, and the velocity of the convection currents of the fluid, the light beam 110 emitted by the laser diode 102 may be diffused as the beam propagates through the heat sink fluid 108. The output window 118 of the heat sink 100 can have optical power and be a lens to focus or collimate the diffused light beam. Alternately, other optical elements such as lenses or mirrors in the optical path of the light beam after emission from the laser diode 102 and fluid heat sink 100 can focus or collimate the diffused light beam.

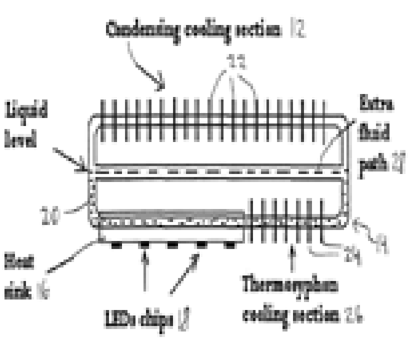
The shape of the heat sink housing 104 can also lessen the dispersive effect of the convection currents of the fluid. The housing can be a hemisphere, a truncated cone with the base adjacent to the laser diode emission surface or a truncated cone with the base surrounding the output window. The exact shape will depend upon the dispersion of the emitted light beam and the convection currents of the fluid. The symmetrical shape of the fluid cavity and the housing centered around the laser diode light beam emission aperture aids in the dissipation of heat and lessens the convection currents from disturbing the light beam in the optical path between the aperture and heat sink output window.

HIGH RELIABILITY COOLING SYSTEM FOR LED LAMPS DUAL MODE HEAT TRANSFER LOOPS

US 8,262,263 B2, Dinh, K.

Light Emitting Diode (LED) lamps are solid state devices that emit light with high efficiency. However, they do not survive high operating temperatures above 120 C, and their efficiency and reliability drop drastically as their temperatures rise above 80 C. In comparison, an incandescent lamp operates successfully above 1200 C. Accordingly, heat dissipation from LEDs is an important problem to address in order to insure long life, reliability, and efficient operation of LED lamps.





A conventional conduction heat sink that consists of a relatively heavy piece of metal with high thermal conductivity, such as aluminum or copper, sometimes having air cooled fins, is marginally applicable for low intensity LED lamps, while high intensity LEDs need more efficient cooling methods such as liquid cooling or heat pipe cooling.

Liquid cooling of electronic components is well known, as taught in U.S. Pat. No. 6,055,154, wherein the back of an electronic chip is exposed to a current of cooling fluid moved by a pump. The concept of liquid cooling by impingement of water jets against the back of a heat sink is shown in U.S. Pat. No. 5,316,075. Although quite effective, liquid cooling requires the use of coolant pumps, controls, blowers or fans, and is therefore quite expensive.

Cooling using a phase change process, such as by using a heat pipe, is also known, as taught in U.S. Pat. Nos. 7,210,832; 6,926,072; 6,910,794; 6,474,074 and others. The connection of a hot chip to a heat pipe is an application in central processing unit (CPU) cooling found in many modern computers. However, most heat pipes have an internal wick structure that is expensive to manufacture and can only be justified in the cooling of high cost electronics such as CPUs. Moreover, heat pipes fail if there is a leakage of their working fluid.

The present disclosure presents a new design of heat transfer loops that can take the heat from heat emitting devices such as LED lamps. The heat is then spread over a large area of cooling fins using phase change in conjunction with liquid circulation of a vaporizable working fluid. Exemplary embodiments of the present disclosure use low cost heat transfer loops without a wick structure. Heat pipes can transfer huge amounts of heat with very small difference of temperatures, as disclosed by Khanh Dinh in several of his patents, including, for example, U.S. Pat. Nos. 6,742,284; 6,745,830; 5,921,315; 5,845,702; 5,749,415; 5,582,246; 5,564,184; 5,448,897; 5,404,938; 5,394,040; 5,333,470; 5,269,151; 4,938,035; 4,827,733 and 4,607,498, all of which are hereby incorporated by reference. Working on the same phase change principle as heat pipes, heat pipe loops are much simpler to manufacture, since they do not require the capillary or wick structure used in heat pipes. They can be made of inexpensive piping surrounded by air-conditioning finned coils, connected together to form a gravity return loop. Moreover, exemplary embodiments of the present disclosure also use a non phase change thermo-siphon loop for added reliability. This portion of the heat dissipating device operates very similarly to liquid cooling, but does not require a pump. Instead, natural convection is used.

The combination of the two heat transfer modes, heat pipe loop and thermo-siphon, insures redundant and efficient heat transfer from the LED lamps, allowing for higher current densities, and therefore more light to be obtained from the same LED lamp, resulting in overall cost savings.

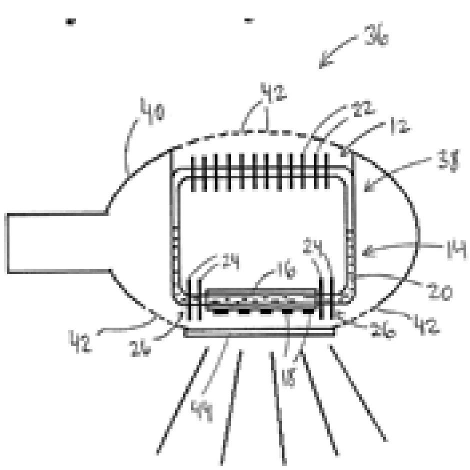
The teachings of this disclosure are different from the state of the art in that no wicking is needed, no capillary is needed, and no pump is needed. The present design is self contained and does not need a thermal contact with the housing of the lamp in order to dissipate heat to the outside, as in some other heat transfer designs that rely on the housing of the lamp to dissipate heat to the outside air.

The efficiency and durability of an LED lamp decreases drastically with increasing junction operating temperatures. For example, the light production of an LED lamp can drop as much as 30% when the junction temperature increases from 60 C to 90 C. Meanwhile, the life expectancy goes from 50,000 hours to a few thousand hours. It is therefore very advantageous to keep LED lamps operating at the lowest temperatures possible.

Whereas true heat pipes only rely on phase change to transfer heat, and therefore are practically empty of liquid except for the liquid portion of the fluid that is captured in the wick structure, the present invention uses both phase change and liquid circulation for cooling. In an exemplary embodiment, the main mechanism for heat transfer is phase change and the secondary heat transfer mechanism is liquid circulation by thermo-siphon effect.

The thermo-siphon mechanism also offers a second level of safety cooling: in case of a loss of vacuum in the heat pipe, the phase change fluid, quite often water, will not change phase, and a conventional heat pipe will be totally ineffective. In contrast in exemplary embodiments of the present disclosure, by the use of thermo-siphoning effect, the claimed cooling devices will still work at a reduced rate in the event of loss of vacuum. The claimed cooling devices are similar in construction to the heat exchangers made of finned coils as taught in U.S. Patents by Dinh, listed above, and can be built using regular machine tools used in the HVAC (heating, ventilation & air conditioning) coil manufacturing industry. In contrast to the applications in HVAC, the claimed cooling devices do not have two coils exposed to the air for air-to-air heat exchange; rather, only one coil is exposed to the air.

LED chips 18 are mounted on heat sink 16, made of copper or aluminum in exemplary embodiments. Heat generated by LED chips 18 is conducted to heat sink 16, which then transfers heat to the cooling device 10. Cooling device 10 is an enclosed tube having a vacuum section 12 and a liquid-filled section 14. In some embodiments, the tube is configured as a loop. A portion of vacuum section 12 is surrounded by cooling fins 22. A portion of liquid-filled section 14 is surrounded by cooling fins 24. Liquid-filled section 14 is in contact with heat sink 16.



In an exemplary embodiment, the working fluid 20 in the liquid filled section 14, such as water, alcohol, or a Freon family refrigerant, fills about 50% of the internal volume of the cooling device 10 and flows to the bottom of cooling device 10 by gravity. A vacuum is created in the cooling device 10 prior to installing the working fluid 20, such that there are substantially no non-condensable gases in the cooling device 10.

Under normal operation, LED chips 18 generate heat which is sufficient, because of the vacuum within cooling device 10, to cause the working fluid 20 to boil in the liquid filled section 14, creating vapors. The vapors raise to the condensing cooling section 12 of the cooling device 10 and transfer heat out of cooling device 10 via fins 22 of condensing cooling section 12. Heat is thereby transferred by phase change from LED chips 18 to the air via fins 22.

Thereafter, the vapors condense, releasing the latent heat of condensation; the condensed liquid flows by the effect of gravity to liquid filled section 14. The net effect of the evaporation-condensation cycle transfers large amounts of heat with very little temperature difference. Some heat transfer also occurs between heat sink 16 and liquid filled section 14. In an exemplary embodiment, liquid is free to move within cooling device 10. Such circulation can occur naturally by convection currents and or by an artificial method of induced circulation such as tilting, slanting, or even pumping.

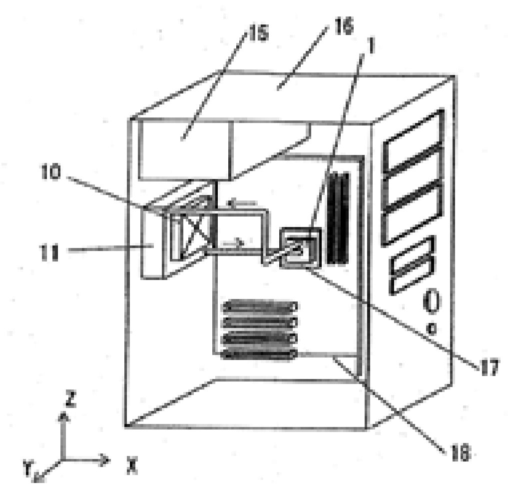
Under failure mode when the vacuum in cooling device 10 is broken, such as by a leak, the working fluid 20 will be unable to boil and will heat up. This heating effect will produce a change in density that in turn will induce a thermo-siphoning effect between the heat sink 16 and fins 24 of thermo-siphon cooling section 26, thereby providing heat transfer by convection and conduction. Thermo-siphon cooling section 26 is created by attaching cooling fins 24 on a portion of liquid filled section 14.

A streetlight 36 uses cooling device 38. The illustrated streetlight shows a housing 40 that gives weather protection and allows for mounting of the streetlight 36 onto a standard electrical pole. In the illustrated embodiment, housing 40 has ventilation perforations 42 to allow for airflow into and out of housing 40 for enhanced heat dissipation.

HEAT SINK APPARATUS AND ELECTRONIC DEVICE HAVING SAME

US 2013/0063896 A1, Satou, k., et al.

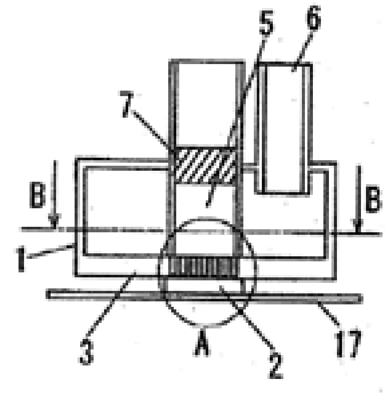
A heatsink apparatus according to a first embodiment of the present invention is provided in a personal computer (hereinafter referred to as a PC) unit; PC unit 16 includes the heatsink apparatus according to the present invention, along with PC components, such as power source unit 15, motherboard 18, and the like. The heatsink apparatus includes box-shaped heat-receiving unit 1, which is connected to socket 17 of a heat-generating body; heat dissipater 11; and fan 10, which cools heat dissipater 11.



More specifically, the heatsink apparatus according to the present invention includes three main components and circulation components. The three main components are box-shaped heat-receiving unit 1, which includes heat-receiving plate 3; heat dissipater 11; and check valve 7, which determines a circulation direction of a working fluid. The circulation components are inlet pipe 5, which connects check valve 7 and heat-receiving unit 1; outlet pipe 6, which discharges the working fluid from heat-receiving unit 1; pipeline 8, which connects outlet pipe 6 and heat dissipater 11; and pipeline 9, which connects check valve 7 and heat dissipater 11.

Heat-receiving plate 3 contacts with heat-generating body 2 and absorbs heat therefrom. Material having a low thermal resistance, such as, for example, copper, aluminum, and the like, is used for the heat-receiving plate. Slits 4 are provided in substantially parallel inside heat-receiving plate 3 of heat-receiving unit 1 and proximate to and immediately above the heat-generating body. Inlet pipe 5 is disposed covering slits 4, such that inlet pipe 5 contacts with heat-receiving plate 3 or has a slight gap with heat-receiving plate 3. Specifically, length W1 of slits 4 is provided greater than pipe diameter D1 of inlet pipe 5, such that inlet pipe 5 covers a central pardon of slits 4 provided proximate to and immediately above the heat-generating body.

When heat-generating body 2 generates heat, the heat, which is transferred from heat-generating body 2 to heat-receiving plate 3, causes working fluid 14 in heat-receiving unit 1 to change its phase (vaporize) on a heat-receiving plate 3 surface (hereinafter referred to as a vaporization surface) inside heat-receiving unit 1. Then, vapor receives the heat as latent heat of vaporization and cools heat-generating body 2. The evaporated vapor passes through pipeline 8 from outlet pipe 6 in a direction of an arrow, and then flows into heat dissipater 11. The vapor, which is cooled inside heat dissipater 11, condenses and liquefies. Heat of condensation associated with the liquefaction dissipates and increases a temperature of the heat dissipater. Then, air is fed from fan 10 provided on the heat dissipater to a surface of heated heat dissipater 11, thus causing heat exchange and eventually dissipating the heat into air. Thereafter, liquefied working fluid 14 passes through pipeline 9 and check valve 7, which is provided immediately before heat-receiving unit 1, and then returns through inlet pipe 5 inside heat-receiving unit 1. Repeating a cycle of the steps above continues cooling.

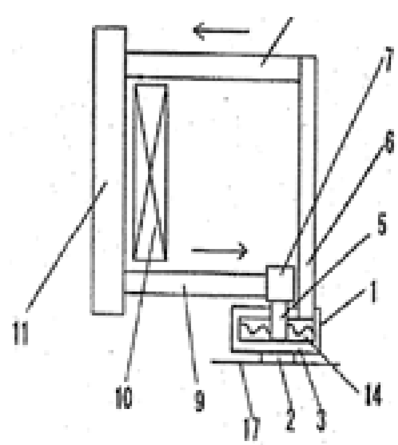


Working fluid 14 flowing in from inlet pipe 5 into slits 4 contacts with the heat-receiving surface most proximate to the heat-generating body when passing through inside slits 4. The working fluid then changes its phase (vaporizes) in an amount according to a heat-generating amount. At this time, latent heat of vaporization is drawn from the heat-receiving surface, and concurrently bubbles form due to cubical expansion associated with the phase change. Since an internal pressure of inlet pipe 5 increases, the bubbles and unvaporized working fluid 14 are discharged in a multiphase flow to outlet pipe 6. Inlet pipe 5 is provided with check valve 7. The pressure increase herein occurs on the outlet side beyond check valve 7, and thus determining a circulation direction of working fluid 14. Bottom thickness h of the slit section is considerably thin compared to heat-receiving plate thickness H.

When slit bottom Thickness h is thin, thermal resistance due to the thickness can be reduced. Even when a heat-generating amount is the same, the working fluid thus reaches a vaporization temperature in a relatively short time and starts vaporization. Thereby, temperature increase is prevented on the heat-receiving surface at an initial stage of heating. Further, providing slits 4 ensures a sufficient vaporization area concurrently, thereby enhancing heat absorption performance.

In order to discharge the bubbles in slits 4 along with unvaporized working fluid 14 by the above-described pressure increase, channel resistance at the gap between heat-receiving plate 3 and inlet pipe 5 needs to be greater than that at slits 4.

Specifically, when no gap is provided between heat-receiving plate 3 and inlet pipe 5 in a portion in which no slits 4 are provided, no working fluid 14 is discharged from the gap between heat-receiving plate 3 and inlet pipe 5 in the portion in which no slits 4 are provided. Thus, the working fluid is only discharged from slits 4, and thereby the bubbles forming in slits 4 can be effectively discharged by the flow of working fluid 14.



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